National Aeronautics and Space Administration

Liquid Propellant Gauging in Low Gravity

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Objectives

- Method to gauge liquid propellants in low gravity
- ± 3% full-scale mass uncertainty or better
- Real-time gauging method
- No fuel used in gauging process
- Works with various tank geometries
- Minimize mass of additional hardware required

Applications

Ares V

http://www.nasa.gov/images/content/133824main_cargo_high.jpg

PVT Gauging Method

- Not currently used with cryogenic propellants
- Used for storable propellants in Earth Orbiting Satellites

Advantages

- No settling required
- Less mass is needed because no fuel is burned in the gauging process
- Current fuel tanks can be used

Disadvantages

- Need noncondensible pressurant gas
- Not instantaneous gauging method—need isothermal conditions

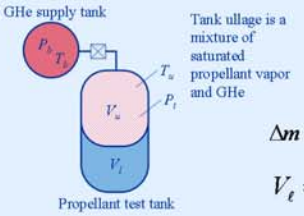
Research Goals

- Determine the accuracy of gauging cryogenic propellants using the PVT method
- Verify model with experimental results in 1g and low-g

Modeling and Analysis

- Conservation of mass of the pressurant gas

Helium is used to pressurize the test tank in order to determine the volume of propellant left in the tank. Helium is noncondensible in H_2 and O_2.

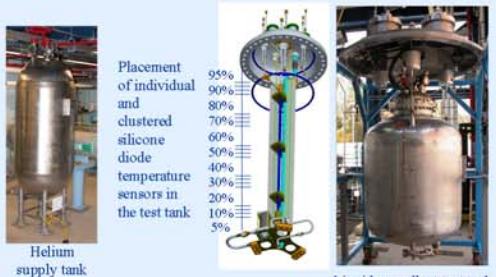


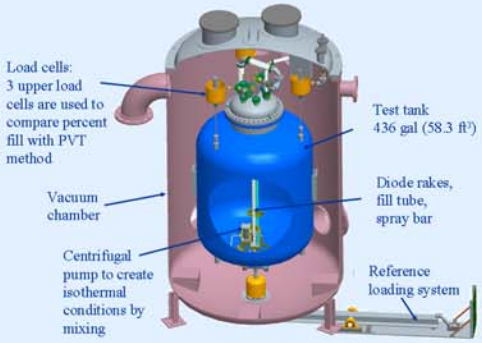
$$\Delta m = (\rho_{bi} - \rho_b) V_b$$

$$V_\ell = V_t - \frac{\Delta m}{\rho_{He_t}}$$

The volume of the helium supply tank and propellant test tank are known. Pressure transducers and temperature sensors are located in each tank. Helium densities are obtained through an equation of state.

Test Hardware





Results

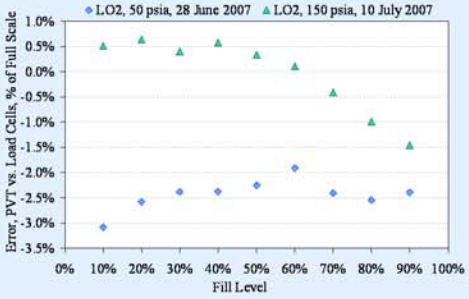
- Gathered test data for LO_2 (50 psia, 150 psia, 250 psia test tank pressure)
- Created tools in Excel and Matlab for design and data analysis

LO2, 50 psia, 28 June 2007

Fill Level, Si diode sensors %	Th R	Ph psia	Tu R	Pt psia	rho_H,t lbm/ft^3	Δm, He lbm	Vu ft^3	PVT Fill Level %	Load Cell Fill Level %	Error %
IC	164.4	414.1								
90%	163.9	401.2	167.1	53.3	0.076	0.3	4.5	92.2%	89.9%	-2.4%
80%	163.2	387.0	166.8	52.5	0.076	0.8	9.6	83.4%	80.9%	-2.5%
70%	163.1	369.7	167.4	52.0	0.073	1.3	17.0	70.8%	68.4%	-2.4%
60%	163.3	358.6	167.3	51.1	0.070	1.6	23.0	60.6%	58.7%	-1.9%
50%	163.0	346.5	168.8	51.8	0.068	2.0	28.8	50.5%	48.3%	-2.3%
40%	162.7	337.1	169.7	51.5	0.064	2.3	34.6	40.6%	38.2%	-2.4%
30%	162.9	330.3	170.4	51.1	0.062	2.5	40.0	31.3%	29.0%	-2.4%
20%	163.2	323.1	171.7	51.0	0.058	2.7	46.4	20.4%	17.8%	-2.6%
10%	162.6	317.1	172.8	52.7	0.056	2.9	51.0	12.5%	9.4%	-3.1%

LO2, 150 psia, 10 July 2007

Fill Level, Si diode sensors %	Th R	Ph psia	Tu R	Pt psia	rho_H,t lbm/ft^3	Δm, He lbm	Vu ft^3	PVT Fill Level %	Load Cell Fill Level %	Error %
IC	164.2	802.9								
90%	163.0	737.0	165.2	144.6	0.284	1.7	6.1	89.6%	88.1%	-1.5%
80%	162.4	674.2	165.7	145.7	0.284	3.5	12.2	79.0%	78.0%	-1.0%
70%	162.1	611.4	165.8	146.7	0.290	5.3	18.2	68.7%	68.3%	-0.4%
60%	161.8	553.6	166.2	147.2	0.286	7.0	24.5	58.0%	58.1%	0.1%
50%	161.2	500.7	167.7	148.8	0.283	8.5	30.1	48.3%	48.6%	0.3%
40%	161.1	455.8	169.1	147.0	0.274	9.9	36.2	37.9%	38.5%	0.6%
30%	161.2	412.5	170.2	147.7	0.271	11.2	41.5	28.7%	29.1%	0.4%
20%	161.3	367.7	171.6	148.0	0.266	12.6	47.6	18.3%	18.9%	0.6%
10%	161.2	329.3	173.5	149.3	0.261	13.8	53.1	8.9%	9.4%	0.5%



Acknowledgments

Special thanks is presented to Dr. Neil T. Van Dresar, Dr. Gregory A. Zimmerli, the Small Multipurpose Research Facility (SMiRF), NASA Glenn Research Center at Lewis Field, NASA Academy, and the Oregon NASA Space Grant Consortium for their generosity and support.

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OREGON NASA Space Grant Consortium